With the Author's Compliments

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ON SECONDARY AND TERTIARY DEGENERATIONS IN THE SPINAL CORD OF THE DOG. *A preliminary communication.*

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Apology for the bare and fragmentary character of the following statement may lie in its preliminary nature.

I must thank the kindness and liberality of Professor Goltz for the greater part of the material used in the anatomical portion of the inquiry.

Up to the present time the extent of that region of the cerebral cortex of the dog, injury to which gives rise to degeneration of the pyramidal tract, has not been experimentally determined. Of the posterior limit even in man Flechsig[1] can only say "die hintere Grenze lässt sich nicht genau angeben".

My material puts the anterior boundary at the anterior boundary of the anterior sigmoid gyrus and at a cross line drawn from the top of the suborbital fissure inwards to the great longitudinal fissure at about right angles to this latter. The lateral boundary seems to lie farther outward from the mid-line than the anterior supra-sylvian fissure. As to the posterior boundary, degeneration of the pyramidal tract may follow a cortical destruction not reaching further forward than a vertical drawn from the most posterior point of the ecto-sylvian fissure. The inconstant position of this fissure lessens its value as a landmark, but it is difficult to find any good landmark, the relative nearness of the crucial sulcus itself to the most anterior and most posterior points of the hemisphere varying in different dogs. It seems that the field of cerebral cortex, destructions in which cause degenerations of the pyramid, although anteriorly fairly conterminous with the region of the so-called motor centres, extends posteriorly beyond them, at least beyond the hindmost marked by Hitzig or Landois; and includes at least in part the region dedicated by Ferrier to "sensory centres."

[1] *Plan des menschlichen Gehirns.*

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To avoid periphrasis, and the theoretical obligations attaching to the terms "motor-sphere", "sensory centres", &c., it seems convenient to apply a term, "cord-area", to all this region of the cortex cerebri which is so directly connected with the spinal cord that lesions in the former induce degenerations in the latter.

The aim of this inquiry at the outset was to find whether or no the site of the degenerated area in the lateral column of the cord varied with varied position of the initial injury in the field of the "cord-area" of the cortex cerebri. It early became evident however that both size and shape of the area of degeneration in the lateral column varied according to the length of time the degenerating process had been allowed play: so much so as to require an estimation of this effect of time, previous to attempting the original problem.

1. At the end of the first sixty hours after removal of a portion of the "cord area" of the cortex no histological change is observable in the pyramidal tract either at the base of the brain, or in the spinal cord, but by the ninth day a change has taken place in both these situations. In carmine-stained cross-sections under the microscope the axis-cylinders of certain nerve-fibres scattered through the pyramidal tract appear less deeply stained than in normal fibres, and not of homogeneous structure as in the normal, but rather coarsely granular; they are also apparently slightly enlarged. The vast majority of the fibres throughout the column are to all appearance perfectly normal. The cells of the neuroglia in the region of the pyramidal tract seem slightly more numerous than in the corresponding part of the opposite lateral column. Neither in carmine, nor in haematoxylin, nor in osmic acid preparations is the area of the pyramidal tract at this time marked out by darker or paler staining from the rest of the lateral column. Yet, despite its non-apparent character in such preparations, the change is already easily to be seen by the naked eye if the tissue has been hardened a few weeks in ammonium bichromate solution. The tract of degeneration appears on cross-section paler than the normal tissue; the pyramid is considerably paler than its fellow; in the lateral column the pyramidal tract gives a large pale spot into which the deep yellow of the surrounding healthy column very gradually fades—so gradually that its limits cannot be fairly represented even in diagram by a line. Once well within the margin however the degree of pallor of the area itself does not become more intense toward the centre; but the degree of bleaching for a given date appears to be in proportion to the size of the lesion in the "cord-area" of the cortex cerebri. This change visible on the 9th day may be traced

throughout the whole length of the pyramidal tract, from the cortical lesion to the upper lumbar region—and appears as advanced at the level of the 2nd lumbar nerve as at that of the 2nd cervical.

2. In the 3rd week the change appears much the same as on the 9th day, but altered nerve-fibres are more numerous, and cells lying in the neuroglia are more numerous. Moreover there seems in the connective-tissue framework wherein the nerve-fibres are set, a disarrangement of the orderliness of the network as compared with the healthy side; the disposition of the meshes is less regular. To the unaided eye the degeneration has become more evident; but the area it occupies in cross-section seems no larger than before. In the fresh unhardened tissue the naked eye detects nothing at this period, nor can it on the ninth day.

3. In cross-sections of the cord, where the degeneration has been allowed to run nearly two months, the disarrangement of the connective tissue network is very apparent, and the main radiate trabeculae are thickened and have numerous thickish side-branches. Some nerve-fibres seem to have disappeared; others still bear the granular, badly-coloured, slightly enlarged, aspect seen in the second week; cells in the neuroglia are very numerous. To the naked eye the degenerated tract is still paler than before. In cross-section it offers an area not quite so large as at first; at the margin the passage from obviously degenerated to healthy tissue has become less gradual; the shape of the area is not altered. By this date, and even so early as the fifth week, the naked eye can find the degeneration in the fresh unhardened cord, as a milky rounded spot, in section, not quite so large relatively to the whole area of the lateral column as the degeneration visible in a hardened specimen. At the base of the brain there is no evident difference in size[1] between the pyramid on the degenerated and that on the undegenerated side; and the cross-sections of the pyramids show no difference in size although, after bichromate preparation, the degenerated may appear almost pure white beside the healthy.

At this time too—the latter part of the second month after operation—a degeneration is found in the lateral column of the cord on the same side as the cerebral lesion—i.e. in the left lateral column if the cerebral lesion be of the left hemisphere. This degeneration is situate in the same dorsal part of the lateral column in which lies the crossed pyramidal tract. The appearance thus given, e.g. in the cervical cord, is as though

[1] This holds only for adult dogs. In young puppies a difference in size between the pyramids is observable a month after the cortical destruction.

degeneration of both crossed pyramidal tracts were following from lesion of one cerebral hemisphere; although one would nevertheless remark that the degeneration in the lateral column on the side opposite to the hemisphere operated on appeared the older and further advanced of the two.

In cross-sections of the cord this new degeneration is at this stage traceable with the naked eye from the third cervical nerve-root through the whole cervical enlargement. For the dorsal and lumbar regions my observations are not complete, but in neither region is it observable by the naked eye. Both to the microscope and unaided eye the characters of this area closely resemble those given by degeneration of the crossed pyramidal tract in the second week after cerebral injury, for it occupies a similar position, is of similar shape, and gradually merges into the undegenerated region by a similar ill-defined edge; and the degree of pallor within that margin is uniform and slight. For reasons mentioned below I propose to call this tract thus degenerated a "re-crossed" pyramidal tract. An experiment shows that this bilateral anatomical change resulting from unilateral cerebral injury has a physiological equivalent. In the dog and the rabbit, five weeks after a destruction in the "cord-area" of the cortex, electric stimuli applied to the degeneration in the corona radiata, after removal of the scar of the original wound, give no movements on either side of the body even when the currents used are very strong; applied to corresponding points of the opposite hemisphere they evoke, when moderately strong currents are used, movements on both sides of the body.

4. Six weeks later, in the fourth month after the cerebral destruction, the degeneration in the opposite lateral column, i.e. in the crossed pyramidal tract, shows still more obvious increase of connective-tissue elements; fine blood-vessels are abnormally numerous, there are still the altered nerve-fibres, and some nerve-fibres seem to have disappeared. To the naked eye the degeneration is whiter, smaller, and more sharply defined than formerly. If the cerebral lesion has been large, the pyramid of the same side as the injury is now obviously smaller than its fellow, especially when the areas of the two cross-sections are compared.

In the lateral column of the same side as the brain lesion, i.e. in the area of the re-crossed pyramidal tract, the degeneration is little changed. What change there is, is in the direction of greater pallor, and sharper edge. But the obvious longitudinal extent of it is greater. It now runs from the region of the third cervical nerve-root to that of the second dorsal, and then again from close above the ninth dorsal to disappear

above the second lumbar. There may be traces of it throughout the gap between the above two distinctly affected districts. The change seems confined to the nerve-fibres; the connective-tissue network shows no overgrowth, its septa are not thickened.

5. In the fifth month, as the result of a very large lesion, the degenerations have the appearances shown in figures 2—12, Plate IV. The references to the figures are given on p. 190. The intensity of the degeneration is meant to be represented by the depth of the stippling. The stippling for the left half of the spinal cord in fig. 5 is rather too deep. The example from which the figures were drawn showed well an essential difference between the degeneration of the two sides.

On the right side of the cord the amount of degeneration shows an unbroken decrease from the brain tailwards; so that, if at any point in the length of the cord the amount of degeneration there visible in section be taken as the unit, in none of the sections above, nearer the head, is the amount less than the unit, and in none of the sections below, nearer the tail, greater than the unit. The decrease however is not regular, but is most rapid just behind the pons, about the decussation of the pyramids, in the cervical enlargement, and in the anterior lumbar region.

In the lateral column on the same side as the cerebral injury the degeneration runs throughout the cord from the posterior end of the decussation of the pyramids to the second lumbar nerve-root. It is present throughout the region of the dorsal nerves, but is not so marked there as it is above and below the dorsal region; it is especially slight between the 4th and 7th dorsal nerve-roots. I believe that it is present also at the base of the brain in the pyramid of the opposite side to the hemisphere injured, but very slight there, the altered nerve-fibres being few and scattered; I fail to find them at all higher than the pons. This degeneration obviously does not show unbroken decrease in amount, from the brain distally; it is far greater in the upper cervical region than in the pyramid; and greater in the lower dorsal than in the middle dorsal region.

On neither side can I trace the degeneration further distally than the root of the second lumbar nerve. Histologically the degeneration of the re-crossed pyramidal tracts differs from the degeneration of the crossed pyramidal, mainly in being accompanied in a far less degree by overgrowth of connective-tissue.

It was notable in the specimen figured on Pl. IV. that the pyramid had not shrunken at all, though the degeneration was of four months' standing; this I am confident is an exception to a general rule.

6. By the middle of the seventh month the pyramid of the injured hemisphere is always much shrunken, even although the cortical injury be not so large as a shilling-piece. It has acquired a smooth surface quite other than the sculptured face of a normal pyramid when hardened in Müller's fluid. The tracery, chiefly due to very various arrangements of the inferior arciform fibres, is lost. At this stage, if the cortex-lesion be quite large, the microscope will find scarcely a healthy nerve-fibre in the whole pyramid. Not only is the area given by the degeneration larger than in any part of the spinal cord, but the degree of completeness of destruction is far greater than in any region of the cord. The pyramid has become a mass of fine fibrous tissue, staining deeply with carmine, and containing a granular debris of rather highly refracting particles; the particles are not, or very little, coloured by carmine; treated with osmic acid they become brown.

Where the pyramidal tract adjoins the subolivary tract (Olivenzwischenschicht), just behind the trapezium for instance, the degenerated bundles of the pyramid have at their peripheries normal fibres, which on cross-section appear arranged in more or less complete rings. As the subolivary tract does not degenerate from cortex injury, these healthy nerve-fibres running parallel with the pyramidal-tract fibres, but forming sheaths round the bundles of these latter, belong probably to the subolivary tract[1]. And I find a similar arrangement shown by sections of this region from a three-weeks old puppy, in which the fibres of the subolivary tract have acquired their medullated sheaths, and the pyramid fibres have not.

The degeneration of the crossed pyramidal tract cannot in the seventh month be traced by the naked eye so far distally along the cord as it could formerly; in my specimen I lose it at about the 10th dorsal nerve-root. Where it can be seen, its cross-section is considerably smaller than in the early months, and has become more circular. With the microscope however it can be traced to the 2nd lumbar nerve-root, and is found throughout to contain but very few altered nerve-fibres, and very many healthy ones, supported by trabeculae of connective tissue thicker and more numerous and less regularly disposed than before. The healthy nerve-fibres are of various sizes, but may be roughly grouped into large and small; the latter appear to be relatively less numerous than they are normally in the dog in this area. The inference is that those fibres of the lateral column which belong to the crossed pyramidal tract are among the finer fibres of that column.

[1] Cf. an observation by Schäfer, this Journal, Vol. IV. p. 323.

In the lateral column of the same side as the cerebral lesion a degeneration is still evident to the naked eye, but in the only specimen which I have of this date, it cannot be traced with certainty between the 1st dorsal and the 8th dorsal nerve-roots. Opposite the 9th dorsal it is very clearly seen, and can be traced distally to just beyond the 2nd lumbar. Within the cervical region it exists from the 4th nerve-root downwards throughout. At the base of the brain the pyramid in and below the pons shows scattered altered fibres.

With this degeneration there is extremely little increase of supporting tissue; in the upper cervical region the fine blood-vessels of the tract are more numerous than is normal.

7. Eleven months after the cerebral lesion the pyramid of the injured hemisphere is still more shrunken. After a large lesion its breadth may be but three-fifths that of the opposite; its area on cross-section shows yet greater diminution, its colour is dead white, its surface is perfectly smooth and unsculptured. After even a large cortical injury, the spinal cord at this date shows no spot of degeneration to the naked eye. Should a trace still be seen, it is in the proximal cervical region of the crossed pyramidal tract; there on cross-section may be perhaps a well-rounded fleck rather less than a millimeter across, semi-translucent and grey in the fresh state, dead white in the hardened cord. Doubtless Charcot's expression "degenerescence grise" is taken from degenerations at this stage. The central point of this spot is situate, in a cross-section of the cord, rather posteriorly to the central point of the large roughly triangular area occupied at first by the degeneration.

But in carmine preparations, and successful osmic acid stainings, the degeneration of the crossed pyramidal tract is still seen with the greatest distinctness throughout the cord to about the 2nd lumbar root. It shows as a fine fibrous scar which carmine, logwood, &c., colour deeply, traversed by very numerous healthy nerve-fibres of various sizes. There are now no ill-staining, granular axis-cylinders; the active stage of the degeneration has probably been over for some time.

By this date however it is with extreme difficulty that any trace of the degeneration in the lateral column of the same side as the cerebral lesion can be shown. The degeneration of the re-crossed pyramidal tracts, even when rife and where most marked, is not accompanied by such an increase of the fibrous connective tissue as is degeneration of the crossed pyramidal tract, and passes away without leaving such a scar. Also in the pyramid of the side opposite to the lesion is no record of any sparsely scattered fibres which it may have lost.

To consider shortly the tracts degenerating in the cord on the same side as the hemisphere operated on.

The dorsal part of the lateral column, in which lie the fibres of the crossed pyramidal tract, admittedly contains some other fibres. My material convinces me that these other fibres are very numerous. For even after destruction of the whole "cord-area" of a hemisphere has removed *in toto* a crossed pyramidal tract, the scar from the degeneration is extremely thickly set with healthy nerve-fibres. When the whole cord-areas of both hemispheres have been destroyed the scars in the two lateral columns appear not quite so thickly set with healthy nerve-fibres, as the scar left by degeneration of a single crossed pyramidal tract. This points to there being among the fibres left over after destruction of a crossed pyramidal tract, fibres which are destroyed by injury to the hemisphere on their own side of the body.

The local variation in amount of the degeneration in the lateral column on the same side as the brain lesion, appears especially correlated to the limbs, and hints at the existence of a system of somewhat short tracts rather than of one lengthy tract like the crossed pyramidal.

This system appears to begin to degenerate after the crossed pyramidal tract is already degenerating in its entire length, and at a time not earlier than the third week, nor later than the end of the second month, after the cortical destruction. Thus there would seem to be between the crossed pyramidal tract and those tracts which one may call the re-crossed pyramidal, a nodal point, at which the process of degeneration is delayed for a time. And such is indicated by results of stimulation of the "cord-area" of the cortex. With quite weak induced currents applied to a suitable spot of the area the movements obtained are on the opposite side of the body and confined to the face. As the secondary coil is approached to the primary, muscles first of the fore-limb then of the hind-limb of the opposite side are convulsed as well. By further increasing the stimuli muscles on the same side the body as the hemisphere stimulated are made to contract. This observation I am well aware merely confirms what has often been recorded, but it has an interest here, in the fact that, as the degeneration process, after involving the whole length of a crossed pyramidal tract, is for a little time arrested before crossing the median line to the lateral column on the same side as the cerebral lesion, so the impulses from the cord-area of the cortex must overcome the resistance of the whole length of the crossed pyramidal tract before they can break down the resistance offered to their crossing the median line. The delay of the degeneration process at

the junction between the crossed and re-crossed tracts, and the resistance encountered there by nervous impulses, indicate that the junction is effected through ganglion cells. Below the pyramidal decussation there appears to be no compact bundle of fibres passing *en masse* across the median line, unless in the anterior commissure. But there are medullated nerve-fibres crossing in the grey matter in abundance, and these may account for the derivation of the re-crossed tracts from the crossed by scattered fibres diffused along the whole length of the cord; and fibres issuing from the grey matter along the medio-dorsal aspect of the lateral columns do seem especially numerous.

In the dog and the rabbit the muscles on the same side as the cortex stimulated which respond most readily to stimulation are those of the neck and fore-limb. It is between the 3rd and the 7th cervical nerves that the re-crossed tracts first show degeneration.

As to the direct pyramidal tract, I can only repeat a statement previously made in a paper by Langley and myself,—that there seems no evidence of its existence in the dog. But of the two views held of the meaning of that tract, the discovery of tracts degenerating in the lateral column of the same side as the cerebral injury destroys the clinical arguments for one. Hughlings Jackson and Flechsig consider the fibres of the direct pyramidal tract to embouch into motor mechanisms for the same side the body as the tract lies. The clinical grounds adduced by Hughlings Jackson[1] are strong; but, if tracts degenerating in the lateral column on the same side as the brain lesion can be found in man as in the dog, these grounds are removed. And one cannot suppose so great a difference between dog and man that in the former the cortex of each hemisphere is bound to both lateral columns of the cord, in the latter to one only.

There seems no reason for thinking the tracts I would venture to call the re-crossed pyramidal are in any way representative in the dog of the pyramidal tract of man.

The tract described as the pyramidal tract by Flechsig from study of the later stages of development of the cord, has been assumed to coincide with that which degenerates after lesions of the cord-area of the cortex cerebri. Comparison of Flechsig's pyramid tract in the puppy with degenerations following complete destruction of the "cord-area" of the cortex throws doubt on this assumption. Flechsig's pyramidal tract seems considerably larger than the area occupied by

[1] Cf. also Charcot, *Leçons sur la localisation*, &c., p. 356.

the degeneration. Throughout the cord the cross-section of Flechsig's pyramidal tract is, roughly speaking, a longish oval with its long diameter dorso-ventral. That of the degenerating cerebral pyramidal tract is more nearly circular; the figures in Pl. IV. show how nearly so.

In the cervical region a fair share of Flechsig's pyramidal tract lies ventral to the roots of the spinal accessory nerve. As the latter pass outward through the lateral columns they are seen black across the yellow field of Flechsig's tract. I have never found degenerating fibres lying ventral to the spinal accessory root-fibres.

Flechsig's pyramidal tract touches the periphery of the spinal cord just in front of the fissure for the posterior nerve-root. In no case and at no level of the cord does degeneration of the cerebral pyramidal tract give on cross-section an area which reaches the periphery of the cord; not even when degeneration of re-crossed pyramidal tract is superposed on that of crossed. I have not found any trace of undue adherence of the pia to the surface of the cord over the most complete degeneration.

In Flechsig's crossed pyramidal tract there must be included fibres lying ventrally, and also dorso-externally, to those which belong to the brain-cortex; and these must be confined to the cord.

The medullated fibres scattered among the non-medullated of Flechsig's crossed pyramidal tract in a three-weeks old puppy do not seem so numerous as the healthy fibres left in the same area of the lateral column after degeneration in the adult dog of both crossed and re-crossed pyramidal tracts. Therefore the fibres of the re-crossed tracts may acquire medullated sheaths about the same time as do those of the crossed tracts, so that by the developmental method it may be difficult to distinguish the one from the other.

In the cord of a dog of Professor Goltz's which had lived after removal of large portions from both hemispheres, the earliest removal dating back nine months before death, and the earliest removal from the "cord-area" probably seven months before death, a peculiar change had occurred which was described in a paper by Langley and myself in Volume v. of this Journal. Mr Langley there proposed to call the change a tertiary degeneration. Its histological characters were those of a chronic myelitis without the sclerosis, and unlike any phase of Wallerian degeneration. The evidence that it affected any one system of fibres was not clear. The term "tertiary degeneration" is however supported by facts observed during the present research. In

the cord of a dog killed 268 days after a large lesion of the anterior part of one hemisphere, including much of the "cord-area," I find the same appearances though of slighter extent. In the cord of a dog from whom a huge portion of the cortex of both hemispheres had been removed in six operations, the first performed 733 days before death, the cord-areas being probably injured twenty-one months before death, the same appearances are well marked. Here they become more and more extensive in passing from the upper cervical region to the upper sacral; in the lower sacral region they are not so advanced. In the cervical region the fibres involved lie chiefly in the median part of the anterior columns—especially about the bottom of the anterior median fissure. Passing distally along the dorsal region, many fibres in the posterior columns are affected as well, and more and more numerously the more distal lies the level of the section. Both Goll's and Burdach's columns are attacked, but especially the latter; and the latter most in its portion adjoining the grey cornu. At some levels Burdach's column contains few unaffected fibres. In the lower dorsal, the lumbar, and the sacral regions the degenerated fibres occur in the posterior nerve-roots, but in the roots are relatively to sound fibres not nearly so numerous as in the posterior columns; they are most frequent in the more ventral bundles of that portion of the posterior root which does not pass at once into the grey cornu. The degenerated fibres are also to be found sparsely scattered through the lateral columns, and among those fibres which traverse the scar left by the degenerated pyramidal tracts. Nowhere have I found them in the direct cerebellar tracts, or in the anterior nerve-roots; an evidence that the change respects certain fibre-systems. In the case mentioned above, where the extent of the change was slight, the fibres involved lay exclusively around the bottom of the anterior fissure, and in a portion of Burdach's column next the grey matter.

Of points in the histology of the tertiary degeneration I hope to speak in a more complete description than the present. It seems however worthy of remark here that, in the same way that the speedy degeneration of the crossed pyramidal tract of the dog, visible throughout the cord to the 2nd lumbar root in nine days after cortical lesion, is accompanied by considerable sclerosis and leaves a fibrous scar, whereas the later and more chronic degeneration of the re-crossed pyramidal tract is accompanied by far less sclerosis, and leaves practically no fibrous scar; so in its turn is the yet more tardy and far more chronic tertiary degeneration unaccompanied by any sclerosis;

it causes no increase of connective-tissue elements. This feature of itself suffices to distinguish the histology from that of the change in tabes dorsalis, despite a similarity in the varicose fibres of the two.

These observations point to the dorsal angle of the lateral columns being occupied by nerve-fibres of several tracts commingled. In the cervical region for instance it contains

(*a*) fibres belonging to the crossed pyramidal tract, from the cord-area of the cortex of the opposite hemisphere.

(*b*) fibres belonging to the re-crossed pyramidal tracts, belonging to the cord-area of their own-side hemisphere.

(*c*) fibres which a tertiary degeneration involves.

(*d*) fibres which are unaffected by the secondary or tertiary degenerations—

i. small and numerous.

ii. large and less numerous.

(*e*) fibres which acquire the medullary sheath at the same time that the fibres from the cord-area of the hemisphere do, but which do not degenerate with them.

(*f*) scattered fibres which do not acquire the medullary sheath at the same time as do the fibres (*a*) and (*e*).

Perhaps (*e*), or (*f*), or both, should be classed with (*c*) or (*d*) or even with (*b*). Figs. 13, 14 and 15, Pl. V, diagrammatically represent the composition of this part of the lateral columns. The explanation of the diagrams is on p. 191.

Corpora amylacea are not found at any stage in the secondary or tertiary degenerations of the dog, a fact hard to reconcile with views held about the formation of these bodies. "Colloid bodies" occur among the zig-zag varicose fibres of the tertiary degeneration.

The distance to which in the dog the crossed pyramidal tract reaches posteriorly, would, by the point to which the degeneration of it is traceable, be placed a few millimeters beyond the third lumbar nerve-root. Nor does the degeneration of the re-crossed pyramidal tract seem traceable beyond that level.

As to whether or no the site of the degenerated area in the lateral column of the cord varies with the varied position of the initial injury in the field of the cord-area of the cortex, I cannot detect that it does. The fibres from each considerable portion of the cord-area seem scattered through the whole thickness of the pyramidal tract in the cord. In the cervical spinal cord however, at the lower part of the

pyramidal decussation and just below it, the pyramid-fibres shoot into the lateral column through meshes of the formatio reticularis in bundles almost entirely composed of pyramid-fibres; here it may be that certain bundles degenerate after destruction of certain convolutions; my examination however is not complete enough to determine this point.

With regard to any hint of the function of the pyramidal tracts given by study of the degenerations, it is notable perhaps that the temporary paralysis and blunted sensibility on the opposite side of the body resulting from operation on a cord-area of the cortex, begin to diminish from the first hours after the operation, and are mending at the very time that the pyramidal degeneration is running actively forward. That the pyramidal tracts are in the dog requisite for volitional impulses to reach limbs and body seems negatived by the fact that the animal can run, leap, turn to either side, use neck and jaws, &c. with ease and success after nearly, if not wholly, complete degeneration of these tracts on both sides. Further, after complete degeneration of one pyramid, there is in the dog no obvious difference between the movements of the right and left sides.

But in view of the possession by each hemisphere of tracts in both halves of the cord this fact becomes less striking; because, although both lateral columns have alike lost a more or less direct connection with the cerebral cortex, at the same time both alike retain one.

The tendon-reflexes are easily obtained in the dog. For the first week after operations on the "cord-area" of the hemisphere they are not so easily obtained on either side of the body; I find no obvious difference between them on the two sides; in all four limbs they seem depressed. During the second week after the operation they recover their normal briskness, and at the end of that time are brisker than normal upon the side opposite to the brain injury. Later they become more exaggerated, and in both the hind limbs the patella reflex and the ischial reflex show about an equal exaltation. To judge in fact from the deep reflexes only one would imagine the dog to be suffering from a paraplegia rather than from a hemiplegia. This course of symptoms agrees closely with the distribution in place and time of the anatomical lesions described above, and the two may be correlated. I have never succeeded in obtaining clonus in the dog. The difference between the recovery of arm and leg frequent in man is not observable in the dog. In young puppies in whom portions of the sigmoid gyrus had been destroyed, I was unable six weeks after operation to detect anything abnormal in movements, and the deep reflexes seemed about normal, and equal on the two sides of the body.

In conclusion, the facts which I would desire to lay stress on are—

That injury to the "cord-area" of the cortex of one hemisphere causes degeneration in both halves of the spinal cord, in the dorsal angle of the lateral columns.

That there is no reason to think this bilateral degeneration is a degeneration of the two crossed pyramidal tracts.

That the clinical symptoms of a unilateral cortex-injury become bilateral and accord with the bilateral anatomical change.

That in the dog after large destruction of both pyramidal tracts voluntary power is so completely retained that defect of motion is observable only as a clumsiness in execution of fine movements.

That in the adult dog at least degeneration of the pyramid tract is accompanied by exaltation of the deep reflexes.

That the pyramidal tracts, as marked out by the date of acquirement of the medullary sheath by the fibres, do not coincide with those marked out by degeneration after destruction of the "cord-area" of the cortex cerebri; the former are larger than the latter, including as well other fibres which do not come from the brain.

That the histology and chronology of the secondary and tertiary degenerations of the spinal cord are not similar to those of the Wallerian degeneration of peripheral nerves.

EXPLANATION OF PLATES IV. AND V.

Plate IV. Brain and cord of dog in the fifth month after large lesion of left hemisphere.

Fig. 1 *a*. Left hemisphere—the outer broken line marks the limit of adherence of the scar to the thickened dura-mater.

Fig. 1 *b*. Uninjured right hemisphere.

Fig. 2. Section through pons Varolii.

Fig. 3. „ through lower olive.

Fig. 4. „ immediately below the pyramidal decussation.

Fig. 5. „ below the second cervical nerve.

Fig. 6. „ „ third „ „

Fig. 7. „ „ fourth „ „

Fig. 8. „ „ fifth „ „

Fig. 9. „ „ seventh „ „

Fig. 10. „ „ sixth dorsal „

Fig. 11. „ „ tenth „ „

Fig. 12. „ „ twelfth „ „

Plate V.

Fig. 13. Diagram to show the constitution of the dorsal portion of the lateral columns of the cord in the cervical region of the dog.

The dotted line marks out the area of the pyramidal tract as laid down by the date of acquirement of medullary sheath by the nerve-fibres.

The smaller circles indicate the distribution of the fibres of the crossed pyramidal tract as laid down by degeneration secondary to cortical lesions.

The larger circles with a central dot indicate the fibres of the re-crossed pyramidal tracts.

The crosses indicate fibres between those of the crossed and re-crossed pyramidal tracts, which do not degenerate secondarily after cortical lesions, but some of which do undergo the tertiary degeneration.

Fig. 14. The same, after destruction of the "cord-area" of the left cerebral hemisphere.

Fig. 15. The same, after destruction of the "cord-areas" of both hemispheres.

Symbols.

py. pyramid.

s. o. upper olive.

R. b. restiform body.

m. o. lower olive.

ac. sp., *sp. acc.* rootlets of spinal accessory nerve, passing outwards through the lateral column of the cord.

P. Rt. posterior nerve-roots.

A. Rt. anterior nerve-roots.

V. a. ascending root of fifth cranial.

VI. rootlets of sixth cranial.

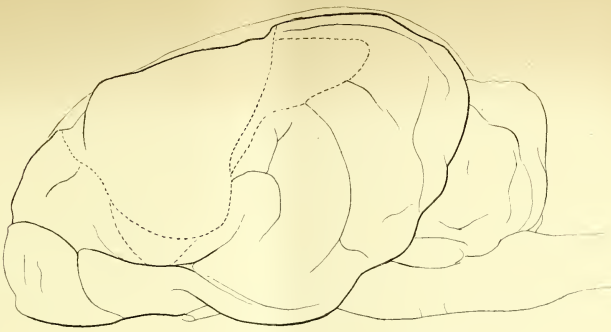
VII. root of seventh cranial.

VIII. root of auditory nerve.

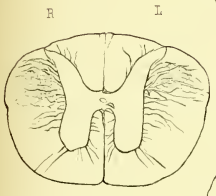
XII. hypoglossal roots.

R. Right side of cord.

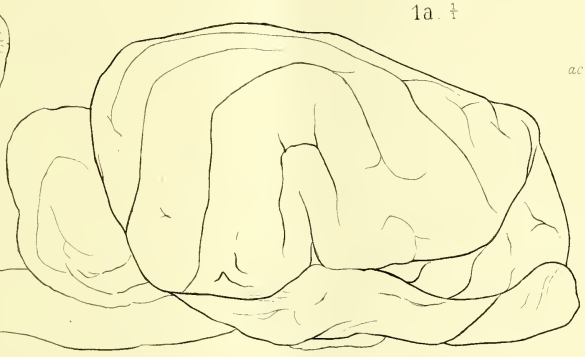
L. Left side of cord.



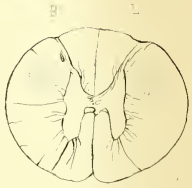
1a $\frac{1}{1}$



4 $\frac{2}{1}$



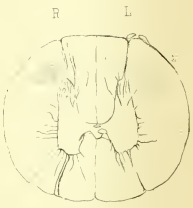
1b $\frac{1}{1}$



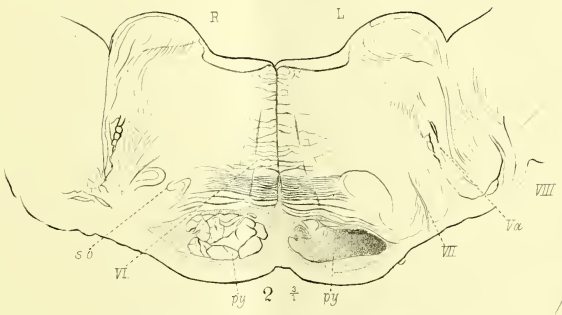
5 $\frac{2}{1}$



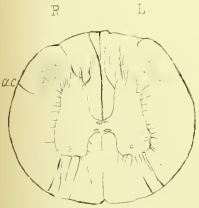
6 $\frac{2}{1}$



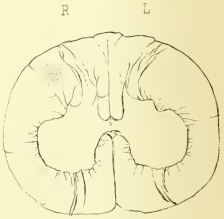
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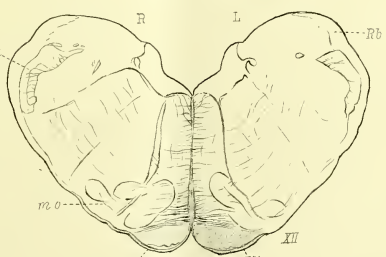
2 $\frac{3}{1}$



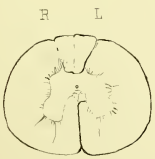
8 $\frac{2}{1}$



9 $\frac{2}{1}$



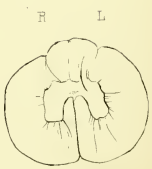
3 $\frac{3}{1}$



10 $\frac{2}{1}$



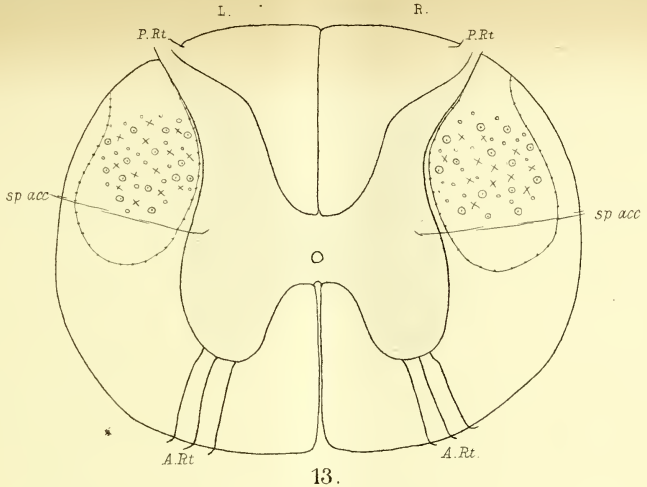
11 $\frac{2}{1}$



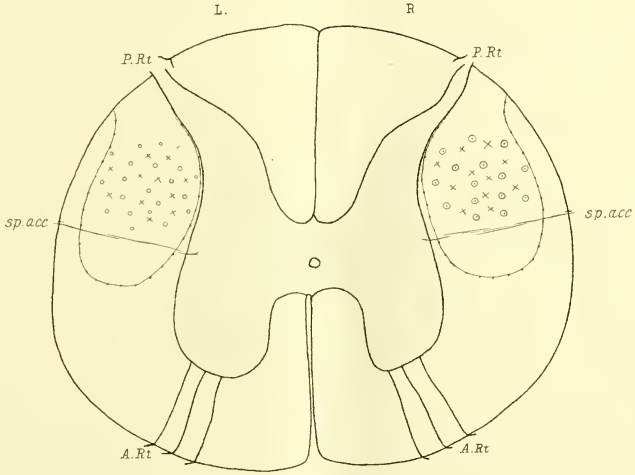
12 $\frac{2}{1}$

C. S.S. dgt.

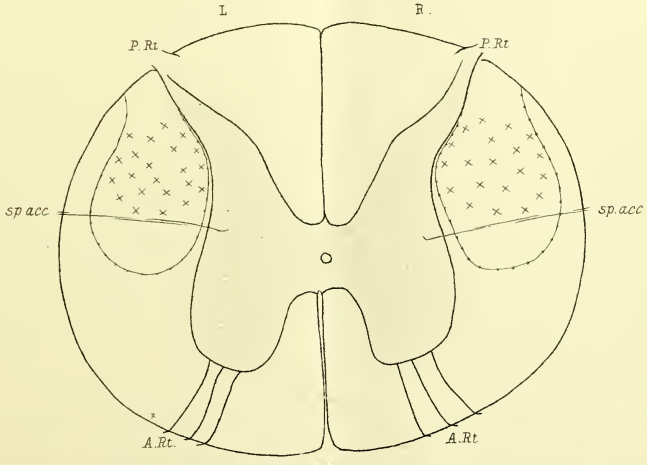
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